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QUARTERLY PROGRESS REPORT

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Report No. 71-101-3
Contract NASW-317

Bellcomm

QUARTERLY PROGRESS REPORT

April May June

1971

D. P. Ling
President

Bellcomm
955 L'Enfant Plaza North, S. W., Washington, D. C. 20024

Report No. 71-101-3
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QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm during the quarter ending June 30, 1971 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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APOLLO/SATURN SYSTEMS ENGINEERING

Mission Planning

Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was prepared for the Apollo Program Director and approved by the Associate Administrator. This issue identified Alphonsus as a tentative lunar landing site for Apollo 17. Descartes had been approved for Apollo 16 in separate correspondence and was shown as approved for the first time in this issue of the document. The document incorporates the latest mission planing requirements for the J-missions.

Support was provided to the Apollo Program Office to assess the landing site visibility in the presence of high-sun elevation angles for the T+24 hour launch opportunity. On Apollo 15 the combination of the distinctive features of the site, the steep descent trajectory and a relatively large azimuth angle between the LM approach path and the sun resulted in an improvement in the surface visibility during portions of the LM descent compared to that for the similar Apollo 14 launch opportunity. These results were presented to the Apollo Program Director. Work is continuing on the analysis of data from the Apollo 14 visibility tests and on the application of these tests to the basic photometric calibration of the moon.

At the request of the Apollo Program Office, the proposed new procedures for the Apollo 15 Descent Orbit Insertion (DOI) and associated trimming maneuvers were examined. It was determined that the procedures and the techniques were essentially the same as for Apollo 14; however, the easterly location of the Apollo 15 site made the recovery from a possible overburn more sensitive. The potential orbit perturbations due to gravity anomalies made the probability of a DOI trim burn maneuver more likely. (1)

The Apollo 15 flight plan and mission rules were reviewed for consistency with the mission requirements as specified in the Apollo Flight Mission Assignments document, the Mission Implementation Plan and the Mission Requirements document.

The MSFN earth orbital coverage for the J-missions was calculated. (2) It was found that the existing requirements for coverage could not be fully met in a 90 nm earth orbit for the entire launch azimuth range of 72° to 100°. In certain cases deficiencies existed in meeting the requirement for two four-minute contacts during each of the first three earth revolutions, and in meeting the requirement for a final four-minute contact during a specified time interval prior to translunar injection.

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(1) Apollo 15 Descent Orbit Insertion and Adjustments, Memorandum for File, W. O. Covington, W. W. Ennis, April 21, 1971.

(2) MSFN Coverage from EOI to TLI for J-Missions 72° to 100° Launch Azimuths, Memorandum for File, S. C. Wynn, June 17, 1971.

A set of available options was derived, using as variables the duration, number and timing of the earth orbital contacts. Based on the results of this study, changes to the tracking requirements in the Apollo Program Specification were recommended and approved.

Space Vehicle Performance

Monthly mission weight and performance status presentations to the Apollo Program Director were continued. In addition, at the request of the Program Director, mission changes were reviewed which affect launch vehicle or spacecraft performance and which will be utilized for the first time on Apollo 15. Included in the presentation was a discussion of the performance reserves for Apollo 15 and the effects of alternate loading procedures for the launch vehicle. Modifications to the methods of computing the LM ascent stage limit weight were suggested. (3, 4)

A report was issued covering the results of a study on optimization of the Saturn V S-IC stage pitch profile to maximize the payload capability. (5) Pitch profile optimization results in slightly lower and faster trajectories into earth orbit and in larger values of the angle-of-attack, α, than the current gravity-turn profile and, therefore, increases the structural loads (that is, bending moments) and aerodynamic heating imposed on the vehicle. These structural loads can be limited to desired levels by optimizing subject to a constraint on the maximum value of the $q|\alpha|$ product, where q is dynamic pressure. Aerodynamic heating was shown to be the limiting factor in any potential payload capability increases from pitch profile optimization for the Apollo-Saturn launch vehicle. For optimized pitch profiles with practical constraints on $q|\alpha|$, the effects of 3σ dispersions on propellant usage, maximum $q|\alpha|$, and aerodynamic heating were not significiantly greater than for a gravity-turn profile. Implementation of such an optimized pitch profile has no apparent adverse effects on vehicle guidance, control or stability.

Pitch profile optimization subject to a constraint of 200 lb-deg/ft^2 on the maximum value of $q|\alpha|$ for a trajectory without dispersions yields an increase of about 1000 pounds in payload capability, but would result in a 3σ-high value of the aerodynamic heating indicator (AHI) that exceeds the current design limit by about 14%. Subsequent analysis, using the AHI as an optimizing parameter, indicates that it is possible to gain about 450 pounds of payload capability while maintaining the AHI at the same value currently obtained for a gravity-turn trajectory.

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(3) Ascent Stage Limit Weight for Apollo 15, Memorandum for File, W. O. Covington, April 14, 1971.

(4) Ascent Stage Limit Weight for Apollo 15, Addressed Memorandum, W. O. Covington, May 25, 1971.

(5) Saturn V Payload Capability Increase from S-IC Pitch Profile Optimization, TM-71-2013-2, D. G. Estberg, K. P. Klaasen, April 21, 1971.

Results of this study have been discussed with MSFC.[(6)] Data from MSFC simulations using pitch profiles provided by Bellcomm as an input agree with the data generated at Bellcomm.

Mission Analysis

During the quarter a substantial effort was directed toward analysis of various aspects of the Apollo 15 mission design. In particular, emphasis was directed to the lunar surface traverse design. The surface equipment performance envelopes and the EVA planning guidelines were examined and modified as a result of both independent analysis and through discussion and interaction with the Centers. Periodic reviews of surface traverse design were held for the Apollo Program Director.

An examination of the nominal traverse design as originally planned revealed that the surface mission could be accomplished within the operational and equipment performance limits, but uncertainties in the performance parameters dictated either a flexible or a more conservative approach to traverse design.[(7)] Subsequently, the traverse design was modified to be both more conservative and more flexible. A similar examination of the walking traverse design (a walking mission is designed in the event that the lunar rover is not available) established that two of the three walking traverses could not be accomplished within the present performance limits and that a significant adjustment in performance limits or traverse design was required.[(8)]

Using the corrected Apollo 14 surface traverse results, MSC provided new guidelines for walking rates which made the existing walking traverses possible. Bellcomm examined this new data for the Apollo Program Director and confirmed that the walking traverses were feasible with the new walking rates; however, due to uncertainties in map distance, wander and actual sampling station location, it seemed prudent to bias the landing site to the south at Hadley-Apennines either through an in-flight redesignation or by relocating the guidance target point. A combination of these two methods was actually recommended.[(9)] This proposed change in landing location would benefit both the nominal and contingency traverse design.

One of the largest uncertainties in the design of the surface mission was in the average speed achievable by the Lunar Roving Vehicle (LRV) over the Hadley-Apennines

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(6) Discussion of Launch Vehicle Pitch Profile Optimization at MSFC, Memorandum for File, D. G. Estberg, K. P. Klaasen, J. L. Marshall, Jr., April 15, 1971.

(7) Apollo 15 Traverse Plan Briefing, Memorandum for File, P. E. Reynolds, April 8, 1971.

(8) Evaluation of Apollo 15 Preliminary Lunar Surface Walking Traverses, Memorandum for File, K. P. Klaasen, April 16, 1971.

(9) Apollo 15 Walking Traverse Review, Memorandum for File, P. E. Reynolds, May 23, 1971.

terrain. High resolution photography is not available for this landing site and obstacles below 20 to 30 meters cannot be identified on the existing photography. MSC assumed a 10 percent increase over the measured traverse path for obstacle avoidance but had made no allowance for any accompanying decrease in nominal LRV speed. Therefore, an analysis which included both factors was undertaken.(10) A statistically representative lunar surface model was used together with a scale model LRV constrained by LRV acceleration and controllability characteristics. From a family of simulated traverses, it was determined that the average speed between specified points would be about 23 percent below the maximum speed due to the combined effects of increase in path length, and speed decreases during maneuvers. These results were formally presented to the NASA Lunar Surface Operations Planning Group, and it was recommended that a specific allowance be made in mission planning for these reductions in average speeds.

A study was made to determine the expected field-of-view during a stand-up EVA at the planned landing site. The analysis showed that a relatively restricted lunar surface view from the top of the LM hatch should be anticipated. Although distant landmarks would be visible, only one of the planned science stations would be visible. A potential solution would be to move the landing site to more favorable terrain such as that available to the south.(11)

The capability was developed to generate computer-plotted scenes of the Hadley-Apennines landing area as it would be viewed by the astronauts. The topographic data for the site in the form of a computer accessible data base was obtained from the TOPOCOM. Panoramic views from six traverse stations were generated. These panoramas were used as aids in familiarizing the crew and the members of the Science Support Room in the Mission Control Center at MSC with what can and cannot be seen at each station (within the accuracy of the data base).

An analysis was continued to establish a graphical method to readily visualize the relation between spacecraft weights, SPS propellant loading and SPS ΔV performance requirements for the Apollo lunar landing missions. Nomographs were developed to permit an examination of mission dependent and independent variables to estimate whether a site could be made accessible by a modification to any one or combination of mission planning parameters.(12)

The attitude of the CSM when the Scientific Instrument Module (SIM) door is jettisoned determines in large measure the subsequent trajectory of the SIM door. The SIM door trajectories for all orientations of the CSM were investigated for

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(10) LRV Lunar Traverse Obstacle Avoidance Study, Memorandum for File, H. F. Connor, D. M. Duty, J. D. Richey, June 4, 1971.

(11) Visibility During a Stand-Up EVA from Selected Locations in the Hadley-North Area, Memorandum for File, H. F. Connor, April 19, 1971.

(12) A Limit-Line Plot for SPS Propellant Budget Evaluation for Apollo Missions, Memorandum for File, W. W. Ennis, April 14, 1971.

possible recontact between the CSM and the SIM door.(13) Four orientations are examined for which recontact is possible, one for the nominal mission (during LOI burn) and three for abort contingencies. Operational considerations add two further constraints which limit the CSM attitude. When all these constraints are imposed simultaneously, a considerable range of attitudes remains possible. The attitude that minimizes the possibility of recontact at LOI yet meets the other constraints is one in which the vector perpendicular to the SIM door is parallel to the periselene vector of the CSM trajectory.

Two studies were completed examining possible contingency missions. The first(14) showed that with post abort mission design modifications a landing mission remained feasible for up to 4-1/2 seconds of underburn at Translunar Injection (TLI) which corresponds to an instantaneous elliptic orbit with an apogee of nearly 143,000 nm. The design modifications would include a lower approach azimuth, a higher sun elevation at landing and deletion of the post-ascent orbital stay. The second study(15) showed that for a lunar orbit only contingency mission, a maneuver could be made 10 hours prior to the predicted nominal mission LOI which would permit satisfying the DPS abort constraint and allow photography of targets selected between 51°N and 37°S from 60°E to 25°W (west of 25°W the latitude envelope begins to neck down). Thus, an Apollo 15 lunar-orbit-only mission could photograph any site accessible to Apollo 17 north of 37°S.

A philosophy for optimal S-IVB impact targeting was developed.(16) Participation with MSC/MSFC in discussions on targeting strategy for S-IVB lunar impact resulted in the generation of a detailed logic tree containing the possible options that may exist during real time.(17)

A study was done for Apollo 16 which showed that the ΔV capability exists to target the LM deorbit maneuver (post-lunar landing and ascent) to a point biased 1 nm crossrange from the ALSEP such that the possibility of being within 10 km of the Apollo 16

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(13) Constraints on the CSM Attitude at SIM Door Jettison, Memorandum for File, L. P. Gieseler, May 4, 1971.

(14) Apollo 15 - Landing Mission Possibilities Following a TLI Underburn, Memorandum for File, G. S. Taylor, June 9, 1971.

(15) Apollo 15 - Potential Photographic Coverage in Retargeting for a Lunar-Orbit-Only Mission, Memorandum for File, S. C. Wynn, May 25, 1971.

(16) A Philosophy for S-IVB Impact Point Targeting and Specification, Memorandum for File, M. T. Yates, April 23, 1971.

(17) Logic Tree for APS-2 Targeting Strategy for S-IVB Lunar Impact, Memorandum for File, R. A. Bass, M. T. Yates, May 28, 1971.

ALSEP is approximately .6. Under these conditions the probability of the ascent stage impacting within 1000 feet of the ALSEP is very low ($<10^{-6}$).[18]

Two important parameters in the targeting of a specific Apollo mission are the LM approach azimuth and the time of lunar landing (or equivalently the sun elevation at landing). A completed parametric study[19] provides the information necessary to determine these parameters for Apollo 16 and 17 within the constraints imposed by (a) LM rescue and the end-of-mission ΔV requirement, (b) scene contrast requirements at LM landing, (c) 210-foot antenna coverage requirements, and (d) the selection of a common approach azimuth for a given time frame. SPS performance data are presented for missions to both Descartes and Copernicus during March, April and May, 1972 (Apollo 16) and December, 1972, January and February 1973 (Apollo 17), for each potential launch opportunity.

Potential bootstrap photography coverage on Appolo 16 was investigated. At 20°E longitude the bootstrap maneuver can provide coverage to a maximum of 18.9°S. The sun elevation at this longitude would be 52°. The SPS propellant used for the necessary 11.25° plane change would make necessary a slow transearth flight time.

The region of the moon accessible during March of 1972 (Apollo 16) is nearly symmetrical about the lunar equator. The maximum latitude range for lunar landing sites is approximately ±38° at a longitude near 25°E. The region necks down to about ±10° at 60°W and 60°E. In December 1972 (Apollo 17) the boundary of accessible area is asymmetrical. Accessibility in the west is similar to that for March but the entire accessible region drops further south in the east. Little of the northeast is accessible. These results[20] were presented to the Apollo Site Selection Board in June and at a prior working level meeting.

In response to the expressed scientific interest in the Tycho site, a special look was taken at the feasibility of an Apollo 17 mission to the vicinity of Tycho. It was found that multiple launch opportunities are available to Tycho during the Apollo 17 time frames of December 1972, January and February 1973, with minor changes to the mission design from the Apollo 15 profile - two days in lunar orbit rather than one prior to landing and use of a Descent Propulsion System (DPS) plus an Ascent Propulsion System (APS) abort constraint rather than DPS alone on the translunar trajectory. These results were discussed with the Apollo Program Director and presented before the Site Selection Board.

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(18) Apollo 16 - LM Ascent Stage Impact Within 10 km of the Landing Site, Memorandum for File, R. J. Stern, June 23, 1971.

(19) The Effect of Approach Azimuth and Sun Elevation at LM Landing on Mission Design for Apollo 16 and 17, Descartes or Copernicus, TM-71-2013-1, R. J. Stern, April 13, 1971.

(20) The Region of the Lunar Surface Accessible During March of 1972 (Apollo 16) and December of 1972 (Apollo 17), Memorandum for File, R. A. Bass, S. C. Wynn, April 29, 1971.

Guidance and Navigation

LM descent and ascent guidance analysis continued. An analysis was carried out of the effects of various Landing Point Designator (LPD) redesignation strategies on vehicle motions and propellant costs.(21) Redesignation delays, deadbands, and biases can significantly increase the vehicle attitude motions and propellant costs. These results were invoked to explain the off-nominal LPD readings on Apollo 14.(22)

Pre-descent landmark tracking and other navigation considerations were analyzed and the reasons for mandatory landmark tracking on Apollo 15 (different from Apollo 14) were reported to the Apollo Program Director.(23) The effects of mascons on Apollo 15 lunar orbit determination and state vector propagation were analyzed.(24) It was determined that the largest probable effect was in down track errors, which can be corrected with target updates(25) and that the probable crosstrack errors were small. The use of artificial satellites to study the lunar density function was analyzed.(26) Two papers by S. L. Levie, Jr., related to gravity modeling were accepted for publication - "Potential Expansion for a Non-Homogenous Oblate Spheriod," in the Journal of Geophysical Research, and "Simple Mass Distribution for the Lunar Potential" in The Moon.

An engineering note concerning a Kalman filter lunar satellite attitude estimator, "Attitude Determination of a Spin-Stabilized Lunar Satellite," by W. O. Covington, was accepted for publication in the Journal of Spacecraft and Rockets.

Lunar Roving Vehicle

Analysis of the performance of the Lunar Roving Vehicle (LRV) navigation system continued. The revised traverses at Hadley were analyzed in terms of navigation

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(21) The Effects of Redesignation Delay, Deadband, and LPD Bias on LM Landing Performance, Memorandum for File, J. A. Sorensen, April 21, 1971.

(22) Explanation for Off-Nominal LPD Readings on Apollo 14, Memorandum for File, T. B. Hoekstra, April 16, 1971.

(23) Pre-PDI Landmark Tracking on Apollo 15, Memorandum for File, W. G. Heffron, T. B. Hoekstra, May 11, 1971.

(24) Possible Effects of Mascon Disturbances on Apollo 15 Orbit Determination and Navigation, Memorandum for File, S. L. Levie, Jr., June 30, 1971.

(25) Pre-Landing Adjustments to Landing Site Position: NOUN 69 in Apollo 15, Memorandum for File, W. W. Ennis, June 21, 1971.

(26) On Determining the Moon's Density Function, Memorandum for File, S. L. Levie, Jr., May 25, 1971.

system performance.[27] Copies of the Bellcomm LRV navigation system analysis program "TRAVEL" were sent to MSC and MSFC at their request. Both the Mission Planning and Analysis Division and the Flight Control Division were given continuing support in the area of LRV navigation.

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(27) LRV Navigation System Realignment Requirements for the Apollo 15 Traverses as Revised January 28, 1971, Memorandum for File, F. LaPiana, April 22, 1971.

Performance and Design Requirements

Communication Systems

Communication systems at KSC were monitored during the Apollo 15 Flight Readiness Test (FRT).[28] The communication support was satisfactory after downlink VHF link troubles were identified and repaired.

The checkout of the Lunar communications Relay Unit (LCRU) was monitored during electromagnetic interference testing in the anechoic chamber with the qualification model of the Lunar Roving Vehicle (LRV). Testing of the flight model LCRU and Ground Controlled Television Assembly in the overall CSM-LM Interface Test was also monitored.

Bellcomm participated in several meetings of the Apollo 15 Television Test Working Group. The specific tests for the elements in the overall Apollo television system were reviewed and additional tests were proposed for inclusion in the end-to-end tests.

Apollo 14 communications anomalies, including the loss of automatic pointing for the LM Steerable Antenna and degraded VHF ranging performance, were discussed with MSC. Additional measurements have been added to Apollo 15 for possible confirmation of the suspected causes of the anomalies.

The performance of the communications link between extravehicular astronauts and the LM on the lunar surface was further analyzed after discussions of requirements and measured performance of link elements with MSC.[29] For most of the planned Apollo 15 traverses, the LM will be sufficiently close to line-of-sight to provide an adequate backup for relay of astronaut voice and data to the earth if the LCRU should malfunction.

A report on a phase-locked loop demodulator for television-type phase modulated signals was prepared.[30] A suboptimum demodulator is suggested by using the Wiener Spectrum factorization technique to find the transmission poles and zeros of the optimum linear loop filter. A simple linear filter is then shown to approximate the optimum loop filter.

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(28) Trip to KSC to Monitor Voice Communications During the Apollo 15 Flight Readiness Test, Memorandum for File, L. A. Ferrara, July 6, 1971.

(29) Meeting at MSC to Review Lunar Surface VHF Communications for Apollo 15, Memorandum for File, I. I. Rosenblum, April 27, 1971.

(30) A Phase-Locked Loop Demodulator for Television Type PM Signals, TM-71-2034-1, W. D. Wynn, May 5, 1971.

In-Flight EVA Capabilities

An operational analysis was completed of the planned Apollo 15 in-flight EVA to determine the ability of the several systems to support the planned EVA.[31] The primary concern identified was the lack of sufficient data on the metabolic energy requirements imposed by the task timeline on the life support system. The review included a comparison of the Apollo and Gemini EVA timelines and system capabilities. It was concluded that insufficient information was available to determine whether or not an incompatibility existed and a conservative approach was suggested. The results were presented to the Apollo Program Office.

Lunar Roving Vehicle Studies

A study was initiated to determine the feasibility of providing TV coverage from a moving LRV. After an examination of the various aspects of the problem and the several available approaches, a system using a gimbal and an optical earth sensor to continuously and automatically point the high gain antenna was identified as the most promising. However, the results of a preliminary analysis indicate a serious weight and power impact on the LRV.

Space Vehicle Systems

Analysis of selected aspects of POGO susceptibility relative to the S-II and S-IVB stages continued at a reduced level. Efforts to interpret the SA-509 (Apollo 14) frequency-time history of the liquid oxygen (LOX) pump inlet pressure failed to yield an explanation consistent with data on the physical parameters of the system. Adjustment of acoustic velocity, effective line length and transducer location were all attempted to make the LOX line frequency track the measured frequency-time history. No explanation could be found which was consistent with all the data.

Work continued on the refinement of the hydroelastic model of the S-IVB stage of the Saturn V Apollo vehicle. Correlations to flight data have been very good; however, there are several modifications to be evaluated before this work is completed. The method used to develop the structural stiffness matrix for this study has been updated.[32]

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(31) Review and Presentation of the Apollo 15 In-Flight EVA Status and Concerns, Memorandum for File, G. J. McPherson, Jr., May 24, 1971.

(32) Static Response - Axisymmetric Shell, Memorandum for File, S. Kaufman, April 6, 1971.

The assessment of the performance of the cryogenic oxygen tanks on Apollo 14 was completed. In an attempt to develop a physical theory for the observed pressure and temperature behavior, a simple model was developed. The model uses heat transfer by radiation and conduction only, and the cryogenic oxygen is considered to be in two distinct volumes of different densities. The model revealed that a locally heated volume (i.e., a low density bubble immediately adjacent to the heater) comprising roughly one percent of the total fluid could lead to the observed pressure and temperature behavior. The results were presented at the MSC Cryogenics Symposium and supplemented the results of other investigators.(33) Subsequently, the principal results of the conference (including the assurance that the tanks will meet the increased demands of Apollo 15) were presented to NASA Headquarters personnel.(34)

Evaluations of the ground test data on the thermal characteristics of the LM supercritical helium tank intended for Apollo 15 led to the conclusion that while there is some slight degradation of the tank's insulation, it is not due to a leak in the vacuum jacket and the tank is therefore satisfactory for flight.(35)

Evaluation continued of in-flight scientific demonstrations for Apollo. A review of a proposed demonstration to grow "copper doped L-alanine" crystals in zero gravity indicated that the experiment definition was not sufficiently complete to meet the stated objectives, and this was a factor in the rejection of that experiment for Apollo 15.(36)

An earlier preliminary analysis of the capability of the CSM J-mission data system to recover lunar orbital scientific data was refined and updated to include new information.(37) Data loss per revolution was determined for various conditions, and operational techniques were identified for minimizing the average data loss and for controlling the spatial location of the loss. It was found that the average data loss per revolution could range from two and one-half minutes to eleven and one-half minutes and typically occurred over the limbs of the moon for the expected modes of operation on the Apollo 15 mission. These updated results were presented to the Apollo Program Director.

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(33) Heat Transfer and Thermal Stratification in the Apollo 14 Cryogenic Oxygen Tanks, Cryogenics Symposium in Manned Spacecraft Center, MSC-04312, S. S. Fineblum, A. S. Haron, and J. A. Saxton.

(34) Apollo Oxygen Tank Performance Presentation, Memorandum for File, J. A. Saxton, June 14, 1971.

(35) Supercritical Helium Tank Presentation to R. A. Petrone, Memorandum for File, J. A. Saxton, June 23, 1971.

(36) Copper-Alanine Systems, Memorandum for File, M. V. Drickman, July 9, 1971.

(37) Review of Lunar Orbital Scientific Data Recovery Capability, Memorandum for File, G. J. McPherson, Jr., May 17, 1971.

Apollo Program Specification

A major revision of the Apollo Program Specification, Revision C, was prepared and approved by the Level I Change Control Board on June 28. This revision incorporated those changes in the system requirements for Apollo which have occurred since Revision C was originally published at the beginning of the development program for the J-mission systems.

Scientific Studies

Apollo Site Selection

In preparation for the June 3 Apollo Site Selection Board meeting, an evaluation of Copernicus as an Apollo site was undertaken.[38] A lowered priority was given Copernicus as a candidate site for the remaining missions because of its proximity to previous Apollo sites and because of the sampling of probable Copernicus ray material at the Apollo 12 site. An Ad Hoc Site Selection Committee for consideration of scientific priorities in site selection was chaired by Bellcomm and convened on two occasions. Presentations were given to the Committee on the geology and other scientific aspects of several candidate sites for Apollo 16 and 17 (Descartes, Alphonsus, and Tycho) and on the traverse capabilities at those sites. The minutes of the Committee's meetings were prepared, and the Committee's recommendations were presented at the Apollo Site Selection Board meeting on June 3.

Apollo Mission Support

Apollo 15

Detailed geologic mapping of the Apollo 15 landing area was carried out [39] to provide basic geologic data for the mission traverse maps for use by the astronauts in their exploration of the area and for use during the mission in the Science Operations Room at MSC. Results of the mapping were incorporated into the Apollo 15 lunar surface traverse plans, and the geologic data were integrated into the surface traverse data package and into the Lunar Surface Procedures Document. The Apollo 15 prime and backup crews were briefed on numerous occasions on the diverse aspects of exploring the Hadley-Apennines region. Assistance and instruction were given to the crews on several field trips. Preparations were made for Bellcomm participation in real-time mission support.

After revision of the Orbital Science Crew Training Program for the specific objectives of the Apollo 15 mission, briefing and training sessions were conducted with the crew on Apollo 15 ground tracks, Service Module instruments, Command Module photography and landing site geology.

Checkout tests of Apollo 15 cameras were observed by Bellcomm members of the Apollo Photo Team, and procedures were suggested for the correction of some of the hardware problems encountered in these reviews. The Apollo 15 photographic

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(38) A Reconsideration of Copernicus as an Apollo Candidate Site, Memorandum for File, N. W. Hinners, April 5, 1971.

(39) Geologic Map of the Apollo 15 Landing Area (1:12,500), J. W. Head, G. Schaber (USGS open file report).

plan was reviewed with other members of the Photo Team and was amended to meet the objectives of Apollo 15 photography, including near-terminator and earthshine photography. Recommendations were provided for film handling and processing.

Analysis was done of brightness contrast at the Hadley Rille, the walls of which were to be photographed during Apollo 15 EVA. This work established the relative merits of different photographic stations (camera positions and view angles).

A Detailed Objective, "Visual Observations from Lunar Orbit," was prepared for inclusion in the Mission Requirements Document for Apollo 15. This Detailed Objective provided twelve visual observation targets to be included in the flight plan.

Criteria for landing site landmark selection were developed, and requirements for onboard graphic aids for support of orbital operations were established.

A section on "Lunar Geology Investigation" was written for the Apollo 15 Press Kit and reports were given at Apollo 15 press conferences.

Apollo 16

In preparation for Apollo 16, the crew was briefed on geological characteristics of the Descartes site and on sampling philosophy. Presentations were made to Apollo 16 Field Geology Investigators on traverse planning.

Apollo 17

A study of the desirability of including a nuclear emulsion experiment on Apollo 17 indicated that operational difficulties outweight the expected gain in scientific information from this experiment. OSSA has subsequently deleted this experiment from Apollo 17 plans.

Lunar Science Experiments

Analysis of the Lunar Sounder Experiment[40] revealed that, the limiting depth for the detection of subsurface stratification is about 150-200 meters in typical lunar surface rock and about 1 kilometer in typical lunar soil. This results from confusion of the signal returned from subsurface discontinuities with the return from surface irregularities.

In an analysis of the Lunar Ejecta and Micrometeoroid Experiment, L033,[41] the response of the variously oriented detectors to the different components of the

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(40) Detection of Lunar Subsurface Structure by the Orbital Radar Sounder, TM-71-2015-3, W. R. Sill, May 12, 1971.

(41) The Lunar Micrometeoroid Experiment, L033, TM-71-2015-2, J. S. Dohnanyi, April 20, 1971.

expected micrometeoroid flux at the lunar surface was studied. Since the high velocity primary meteoroids are effective in ejecting a profusion of secondaries from the lunar surface, the secondaries should constitute the majority of particles detected by the experiment. The analysis provides a theoretical basis for the use of the experiment in the evaluation of different models of the lunar micrometeoroid environment and the interaction of micrometeoroids with the lunar surface.

Participation in the thermal design review of the Traverse Gravimeter led to an independent computer study of that instrument's thermal performance under a variety of mission environments. The study indicates that the Traverse Gravimeter should perform adequately, provided that the actual experiment hardware will meet design specifications.

Analysis of the thermal design of the Surface Electrical Properties Experiment[42] indicated that a proposed dust cover for the optical reflectors, used to reject solar heat during traverses, may actually aggravate the thermal problems should the dust environment be severe.

Lunar Science Studies

Photogeologic study of the Hadley-Apennines region, which continued throughout the quarter, resulted in a geologic map. Likewise, a less detailed geologic map of the Descartes region was prepared for use in preliminary Apollo 16 mission planning.

The Apollo 14 Hycon photography of a segment of the lunar highlands east of Descartes [43] does not reveal exposures of bedrock, and, in view of the limited chances for acquisition of ancient lunar material, that region was rejected for future landings. A study was also performed of three Apollo 14 targets photographed on the far side of the moon.[44] An invited paper on lunar volcanism, "Volcanic Features in the Lunar Highlands," was prepared for presentation at the forthcoming joint meeting of the International Association of Planetology and the International Association of Volcanology.

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(42) Thermal Design of the Surface Electrical Properties Experiment, Memorandum for File, M. T. Yates, June 1, 1971.

(43) Hycon Photography of the Central Highlands, contribution to the Apollo 14 Preliminary Science Report, NASA SP-272, 1971, F. El-Baz, J. W. Head.

(44) Volcanic Features in the Farside Highlands, contribution to the Apollo 14 Preliminary Science Report, NASA SP-272, 1971, F. El-Baz.

A preliminary analysis was conducted of four unusual near-terminator photographs taken during the Apollo 14 missions.[45,46] It is evident that in these photographs many geologic features stand out in a manner not normal in conventional lunar photography.

A three dimensional analysis of gas transport in the lunar atmosphere[47] (undertaken in anticipation of the deployment of mass spectrometers in lunar orbit and on the lunar surface) provides values for gas densities and fluxes at the anticipated locations of gas measurement. The analysis treated several models, each assuming a different global gas source model. Results of this study, when used with actual lunar data, will assist in discrimination between the models and in understanding the dynamic processes shaping the lunar atmosphere.

A review of Apollo 11, 12 and 14 and Luna 16 sample and geophysical data demonstrates the great increase in lunar knowledge derived from sample analysis and in-situ geophysical measurements. It also emphasizes the value of pre-Apollo lunar scientific studies as a basis for interpretation of the new data. The diverse threads of information on the moon are woven into a unified model of lunar evolution in a paper by N. W. Hinners, "The New Moon: A View," accepted for publication in Reviews of Geophysics and Space Physics. At the recent COSPAR meeting in Seattle, Washington, an Apollo 14 session was arranged, comprising reports on scientific data from that mission.

A book by T. A. Mutch, "Geology of the Moon: A Stratigraphic View," was reviewed by F. El Baz for publication in the American Journal of Science and by N. W. Hinners for publication in Icarus.

General

An invited paper, entitled "Current Evolution of Micrometeoriods" presented by J. S. Dohnanyi at the IAU Colloquium #13, demonstrates that the evolution of the population of micrometeoroids is primarily governed by radiation effects, while that of larger objects is governed by disruptive collisions and gravitational effects.

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(45) Near Terminator Photography (within 1/2°) Obtained on Apollo 14, TM-71-2015-1, D. D. Lloyd, April 20, 1971.

(46) Apollo 14 Near Terminator Photography, contribution to the Apollo 14 Preliminary Science Report, NASA SP-272, 1971, D. D. Lloyd, J. W. Head.

(47) Density and Flux Distributions of Neutral Gases in the Lunar Atmosphere, TM-71-2015-4, T. T. J. Yeh and G. K. Chang, June 24, 1971.

Weight Reporting

Skylab Weight and Performance reports for the months of April, May, and June were prepared, summarized for the Skylab Program Director, and issued.

Mission Sequence

A concept was defined for a low-cost portable beacon to serve as a target for Experiment S191 (Infrared Spectrometer) during periods of night observations.(48) A narrow beam of light is slewed repeatedly in a vertical plane nearly coincident with the Orbital Assembly's (OA) orbit plane to provide a flashing beacon, as viewed from orbit. The width of the light beam permits it to be seen from the OA if the beacon is positioned within a few miles of the spacecraft's ground track. Expressions were derived for the luminous intensity required for visibility from orbit. For beacon slewing rates as high as 0.5 cycles per second the intensity required for night-time visibility does not exceed 1.2×10^5 lumens/steradian over the range of zenith angles for which the target and experiment optics will be in line-of-sight contact. It was shown that commonly available searchlights have more than adequate candlepower to assure night-time visibility through clear air. The AN/TVS-3 searchlights used by NASA for launch pad illumination in the Apollo Program provide luminous intensities three orders of magnitude greater than required. Candlepower requirements for a target marker on the sunlit side of the earth were shown to be considerably more severe than for night-time target markers. Intensities on the order of 10^9 lumens/steradian would be required.

The visibility of the OA from a CSM during rendezvous was analyzed, and it was shown that light reflected from the OA may not be detectable when the CSM is over the earth's sunlit hemisphere unless the earth is kept out of the observer's field-of-view.(49) However, if the condition is met the OA will be visible whenever it is in direct sunlight during the last two orbital revolutions of the rendezvous. It was found that for a representative SL-4 mission, the OA's reflected light will give it the appearance of a third magnitude star or better when it is in direct sunlight beyond 4.2 hours ground elapsed time (GET). The OA will appear brighter than a first magnitude star for a brief period at approximately 5.7 hours GET.

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(48) Optical Beacons for Acquisition and Tracking of S191 Targets during Night-Side Passes, TM-71-1025-2, D. J. Belz, April 22, 1971.

(49) Visibility of Orbital Assembly from CSM During Rendezvous, Memorandum for File, D.J. Belz, June 28, 1971.

An updated version of the Automated Task Scheduler (ATS) computer programs was prepared and documented.[50] Changes were made to increase the operational flexibility of the programs and to expand the information content of the program output. Modifications included the addition of diagnostics to assist in timelining tasks that are difficult to schedule, the expansion of input data options to permit new variables to be defined at intermediate points in the scheduling process, and an addition to the Data Processor input structure to permit direct acceptance of data from ATS ephemeris tapes.

In addition, the Interactive Schedule Generator (ISG), a computer program designed to produce timelines of inflight activities for manned space missions, has been added to the Automated Task Scheduler (ATS) System.[51] The program is designed as a functional replacement for the ATS Schedule Generator. Though both programs use the same window-filling algorithm, the ISG can be used in a conversational mode from remote typewriter terminals. The capability for interactive processing eleminates many of the operational restrictions in the ATS that resulted from the limitations of batch processing and facilitates trial-and-error solutions to difficult scheduling problems.

Flight Mechanics

Even though the probability of a collision between the Skylab and a piece of orbiting debris is quite low - on the order of .03% - it seems prudent to take action to detect and avoid a collision if the effort required is not unreasonable and if there is a reasonable expectation of success. A recent study showed that with the expected accuracy of NORAD tracking, a collision between the Skylab and a piece of orbital debris could be predicted with only a one to ten percent chance of being correct. Since even this degree of accuracy would require a significant increase of NORAD manpower, and there are many objects which are too small for NORAD to track at all, an active orbit collision detection and avoidance capability does not appear justified at this time.[52]

The currently baselined Skylab CSM launches leave the spent S-IVB stages in an 81 x 120 nm orbit. Approximately one day after launch the stages will reenter the atmosphere with the points of entry and impact anywhere along several orbit ground tracks. To provide for predictable impact areas, a launch profile was devised that

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(50) The Automated Task Scheduler/Version 2, Memorandum for File, A.B. Baker, April 30, 1971.

(51) The Interactive Schedule Generator, Memorandum for File, A.B. Baker, June 30, 1971.

(52) The Predictability of a Collision Between the Skylab and a Piece of Orbital Debris, Memorandum for File, D. A. Corey, R. C. Purkey, V. Thuraisamy, June 17, 1971.

makes possible a well controlled oceanic impact for the S-IVB stages.(53) The profile features an off-perigee insertion into an orbit with a 120 nm apogee altitude and a relatively low perigee altitude. The CSM would perform a propulsive maneuver at its first apogee to achieve an 81 x 120 nm orbit. The S-IVB would continue on its insertion orbit, enter the atmosphere on its first revolution, and impact in a preselected ocean area. This S-IVB disposal capability is obtained for no penalty in launch vehicle performance or launch opportunities, and no hardware or software modifications to the launch vehicle or spacecraft are required. The current baseline rendezvous profile may be used.

The Skylab cluster will generally perform a momentum dump maneuver once each orbit over an arc of central angle centered near orbit midnight. All or most of each dump maneuver will typically take place in darkness. At times during the mission when beta (the angle of the solar vector to the orbit plane) exceeds about forty degrees, a significant portion of each dump maneuver will be performed in daylight. There will be at least four days during any 236-day mission when every dump maneuver will take place totally in daylight, irrespective of the SL-1 launch date and time. The thermal design of the Skylab must be capable of handling this situation.(54)

Electrical Power System

A study of prior flight and ground experience with nickel-cadmium battery cells concluded that the life of the Airlock Module (AM) batteries could be extended by reducing the amount of overcharge. A review of the charge control system was recommended.(55) Such a review was conducted at MSFC with support from Goddard Space Flight Center and Bellcomm. As a result of this review the constant-current trickle charge, which follows voltage limited charge, is being reduced giving an increased expected battery life.

The detailed performance of the AM and ATM electrical power system was determined for a sample mission day.(56) A network model was used to determine loop currents, bus and interface voltages, and loads on each power supply bus as a function of the same timeline. State-of-charge profiles for the AM and ATM batteries were then determined. The sample day was very active; loads averaged 6650 watts for the

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(53) Controlled Oceanic Impact for Skylab S-IVB Stages, Memorandum for File, W.L. Austin, P.H. Whipple, June 17, 1971.

(54) Skylab Daylight Momentum Dump Requirements, Memorandum for File, E.W. Radany, June 30, 1971.

(55) Prior Experience with the Skylab Airlock Battery Cell, Memorandum for File, W.W. Hough, March 31, 1971.

(56) Evaluation of the Skylab Electrical Power System for a Particular Mission Day, Memorandum for File, J.J. Sakolosky, June 28, 1971.

24 hours with a peak of 8470 watts. At an AM regulated bus no-load voltage setting of 29.2 volts, which was required to maintain CSM/MDA interface voltages above lower limits, the maximum battery depths-of-discharge were 31.2% and 26.7% for the AM and ATM respectively. The maximum AM depth-of-discharge is greater than the desired 30% limit for solar inertial orbits, but in view of the high level of activity assumed for the sample day, this is not a cause for concern. Average depths-of-discharge at sunrise for the 15 orbits were 26.8% for the AM and 24.1% for the ATM.

Attitude Control

The capability of the Skylab Control Moment Gyroscope (CMG) System to execute required desaturation maneuvers was assessed.(57) Unidirectional torques tending to saturate the CMG's arise from the gravity-gradient field, aerodynamic drag, and the venting and leakage of spacecraft atmosphere. The maximum angular velocity required during the desaturation maneuver was found to be .028 degrees/sec and the maximum rotation angle is 11.7 degrees. These requirements can be met by the CMG system without assistance from the Thruster Attitude Control System (TACS).

In the event of a failure of the primary system, contingency means of providing attitude control of Skylab were studied.(58) These methods presume the use of reaction thrust systems on the Orbital Workshop (OWS) and/or the CSM. The Quasi-Inertial (QI) mode (primary among the spectrum of available alternatives) offers two advantages over competitive alternatives. It is closely related to the primary solar-inertial mode and results in little or no impact on subsystems, and it leads to the best fuel economy and longest mission duration. Mission duration attainable using the Quasi-Inertial Mode and both OWS and CSM reaction thrust control is estimated at 117 days.

As part of the Skylab artificial gravity investigation, a study of structural wobble damping was carried out.(59) The wobble motion is assumed to arise from crew motion and is modeled as a random process. Root mean square response of the resulting motion was determined by solving a matrix equation for the state covariance matrix. It was found that although structural damping is small in the sense that the time constant is about two hours, it nevertheless is sufficient to hold the wobble angle to about

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(57) Skylab Typical Momentum Desaturation Maneuvers, Memorandum for File, W. Levidow, June 1, 1971.

(58) The Quasi-Inertial and Wide Deadband Modes ad Backup Attitude Options for The Skylab Mission, Technical Memorandum TM-71-1022-3, B. D. Elrod, June 19, 1971.

(59) Structural Wobble Damping of a Spinning Skylab, Technical Memorandum TM-71-1022-2, P. G. Smith, April 21, 1971.

one degree root mean square. Near the critical point at which ballast boom flexibility gives rise to unstable motion, the results were found to be sensitive to the way in which crew motion is modeled.(60)

Thermal Control

A subroutine was written for improving the descriptive input of figures and locations to be used in the radiation view factor program RAVFAC and VUFACT.(61) This subroutine, EANCAL, permits expressing the Euler angles and other input parameters required by RAVFAC and VUFACT in Cartesian coordinates. Background, analysis, and use of the EANCAL subroutine were presented to GSFC, MSC, and MSFC. Other studies to provide the capability to determine figures intersections and angular orientations were continued during the quarter.

A silhouette substitution technique was developed for obtaining more accurate view factors from the radiation view factor program, CONFAC II.(62) In the CONFAC II subroutine SILFAC, a configuration factor is computed from the projected silhouette of a surface. Frequently, SILFAC cannot define this silhouette. When this occurs, the point configuration factor is set equal to zero and the resulting surface view factor is in error. The developed technique avoids this problem and provides more accurate view factors by substituting an existing silhouette selected from the most suitable neighboring points. This technique was described and a copy of the modified program was presented to MSC.

Thermal model simplification and reduction techniques developed for Skylab module models have been applied to the OWS. These techniques and the resulting OWS model were summarized in a briefing given to MSFC.

A new subroutine was written for the thermal network analysis program, CINDA.(63) This routine, CNDSNR, is aimed at radiation-dominated, steady-state heat flow problems that cannot be solved by existing steady-state CINDA subroutines. The new routine uses the Newton-Raphson iteration algorithm which always converges. The existing routines use the Gauss-Seidal algorithm which may be divergent in non-linear problems.

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(60) Spinning Flexible Spacecraft Wobble Motion and Its Dependence on Flexibility, Memorandum for File, P.G. Smith, June 16, 1971.

(61) Subroutine EANCAL to Facilitate use of the MSFC RAVFAC and VUFACT View Factor Computer Programs, Memorandum for File, L.K. Hawkins, J.W. Powers, June 18, 1971.

(62) A Silhouette Substitution Technique for Obtaining More Accurate Radiation View Factors of Solids and Multiple Surfaces from CONFAC II, Memorandum for File, A.W. Zachar, May 26, 1971.

(63) A Steady-State Solution for Radiation Dominated Heat Flow Problems, Memorandum for File, V. Thuraisamy, June 2, 1971.

Communication Studies

Bellcomm was represented on an MSFC team which reviewed Skylab Experiments S193, M171, M512, T027, S150, S055A, S054, S056, and the Proton Spectrometer to determine their susceptibility to corona. Only M171 and M512 were judged to be adequately protected against corona.

After the MSFC review, Bellcomm was requested to review the S193 experiment in greater detail. Recommendations were made but time scheduling prevented their implementation before thermal vacuum testing during which S193 experienced a high voltage breakdown failure. The contractor for S193 is now making modifications and will perform an additional thermal vacuum testing.

Bellcomm also participated in a review of possible corona problems in the VHF quadriplexer and coaxial switch being used in Skylab. The margin of safety (for rf voltage breakdown) is considered low for these vital communication components which must operate through launch depressurization.

Contingency EVA

In the event it becomes impossible to use the Skylab Airlock for a nominal EVA, a study of contingency modes of operation was performed to detail alternatives.[64] A two-man EVA to the ATM can be conducted using the oxygen, water, and electrical umbilical connections in the STS on the MDA end of the Airlock. Egress is possible through the Gemini hatch (if usable) or through the MDA spare docking port. A one-man, gas-cooled EVA from the CM IVA station through the CM hatch is possible if sufficient oxygen remains in the SM cryogenic tank to provide the required flow rate. The selection of a contingency mode of EVA depends on the failure that prevents nominal operation.

Experiments

A review of the expected performance of Skylab Experiment S192 (Multispectral Scanner), was undertaken at the request of the Program Director. Factors leading to the decision to drop the high spatial resolution channels were examined. Based on available data, the high resolution channels would probably have realized a Noise Equivalent Change in Reflectance (NE$\Delta\rho$) of from 4% to 10% against a specification limit of 1%.

Estimates of the performance of the revised system wherein higher spectral resolution was substituted for high spatial resolution on some channels were limited by available data. Based on information available, it appears that several channels of the revised system may not meet the specification.

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(64) Contingency EVA on Skylab, Memorandum for File, W.W. Hough, June 24, 1971.

The capabilities and deficiencies of Experiment T025 (Coronagraph Contamination Measurement) were examined and the results presented to the Program Director. It was shown that of the three experiment objectives, one cannot be met because of lack of instrument detectivity, and meaningful data which would satisfy the other two objectives will be difficult to realize with the film/camera combination used in the experiment. The specific conclusions, discussed more fully in a subsequent report,(65) were that the film and lens-focal-length combination limits particles that can be resolved to those greater than 0.15 mm; that the instrument detectivity precludes solar F corona observations; and that, although bright particles may be detected and counted, further data interpretation is limited.

A presentation was made to the Skylab Program Director comparing the two urine systems now under development for supporting medical experiments. It was concluded that, until the design of the systems becomes more firm, no baseline should be selected.

Bellcomm participated in the evaluation of the S082B (Chromospheric XUV Spectograph) experiment grating failure. It was determined that the failure was due to migration of gold into the aluminum of the overcoating.

Film

As the result of concern about possible degradation of Skylab photographic films, a review has been made of the factors affecting film response.(66) Film is used for a variety of purposes in space and can provide accurate results if care is taken to avoid non-uniformity of response among individual film samples that can arise in the manufacturing process, calibration, and development.

Conditions during storage, handling, and exposure can promote changes in response. To some degree, the effects of temperature, humidity, atmospheric composition, radiation and length of storage can be determined by tests. However, in addition to the uncertainty with which the changes can be evaluated, individual film samples change non-uniformly when subjected to identical conditions. Wherever reliable test data could be cited, it has been presented to illustrate the amount of change to be expected for a specific film type and the range that might be found for other types. The effect of the changes on experimental measurements has been estimated.

Although the test data available on all Skylab films is incomplete, it is apparent that in some cases film changes will be large enough to greatly reduce the accuracy of the recorded measurements. Inflight calibration of some form, and possibly improved storage conditions, will be required.

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(65) Objectives, Implementation, and Limitations of Experiment T025, Memorandum For File, T.C. Tweedie, Jr., May 21, 1971.

(66) The Effects of Change in Skylab Film Response, Memorandum for File, N.P. Patterson, June 30, 1971.

A presentation was made to the Skylab Program Director reviewing the effects of environment on film to be used for Experiments S082A (Coronal XUV Spectroheliograph) and S082B (Chromospheric XUV Spectrograph and XUV Monitor).[67] Recommendations made included moving the storage location of some of the film, additional testing, and development of detailed plans for film calibration.

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(67) Presentation on Effects of Storage Environment on Film Used in S082A and S082B ATM Experiments, Memorandum for File, N. P. Patterson, W. Strack, May 7, 1971.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING

Manned Space Flight Experiments Program Studies

Task Order No. 36

Guidelines for a biomedical-behavioral program were prepared.[68] Task priorities for specific problem areas were identified and strategies outlined for meeting the goals of long-term support of man in space. The studies suggest that the highest priority be given to: (a) the effects of weightlessness on circulatory and musculoskeletal phenomena; (b) an optimal set of physiological indices for evaluating crew stress status; (c) monitoring and evaluating individual emotional adjustments, interpersonal relations, and task performance; and (d) the effect of orbital flight on biological periodicities. Additional considerations of safety and cost dictate the integration of biomedical-behavioral observations within the mission protocol with results available during the mission to guide key decisions and assess crew performance. These strategies will benefit ongoing missions by increasing safety and minimizing interference with other mission objectives.

The potential of the Space Shuttle operating in the sortie mode to provide an entirely new way of performing space research is described.[69] The sortie mode has the following advantages: (a) it is economical, (b) many flight opportunities are possible, (c) it is flexible, and (d) it enables wide participation. In order to provide these features, the Shuttle must conform to certain operational and design requirements which consider the sortie mode as a major use of the Shuttle. Among these requirements is the capability to sustain seven to ten scientists or engineers on-orbit for two to four weeks.

In the continuing effort of reporting on the operation of large facilities to conduct experiments, an analysis was made of Kitt Peak National Observatory.[70] It is hoped that the procedures and policies of this ground based facility will be instructive in planning and utilizing large manned space facilities. Of particular interest is the role of the facility management and its interactions with the scientific community, government agencies and private industry.

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(68) A Biomedical Program for Extended Space Missions, Volume II, Memorandum for File, L. F. Dietlein (MSC/DA), B. A. Gropper, W. E. Hull (MSC/DA), A. N. Kontaratos, R. S. Mach and R. E. McGaughy, May 7, 1971.

(69) Space Shuttle Sortie Mode Presentation, Memorandum for File, D. B. Wood, June 30, 1971.

(70) Kitt Peak National Observatory: Model for a Space Facility, Memorandum for File, A. R. Vernon, D. B. Wood, May 17, 1971.

Advanced Technology

Task Order No. 37

The possibility of hard ice forming and adhering to the exterior of the heat sink boosters such as those under consideration for the Space Shuttle was reviewed.[71,72] It was concluded that there is a high probability that ice will form on uninsulated cryogenic tankage during rainstorms. As a result, a Space Shuttle of this type launched during or shortly after rain might incur a liftoff weight penalty or suffer possible damage to its aerodynamic control surfaces if the ice were to break loose. It was suggested that film coatings such as Teflon could substantially reduce the thickness of ice which would hold fast to the tankage.

The use of flywheel energy storage for Space Shuttle power systems was compared with the Shuttle baseline systems which consist of a H_2/O_2 turbine driven auxiliary power unit (APU) used during launch and reentry and fuel cells used during orbital operation.[73] Flywheel systems were considered for three possible applications: (a) to accommodate APU peak or surge loads, thereby permitting the turbine system to be smaller, (b) to provide all APU power with energy stored in a flywheel, and (c) to supply all APU and on-orbit power in combination with a solar array. For the nominal seven day mission the flywheel systems were found to offer no weight advantage in any of the three cases. However, the use of flywheel energy storage for peak loads might ease the development of the conventional APU by relaxing the control, transient and throttling requirements of the combustor turbine unit. For missions longer than ten days, a solar array-flywheel system can be lighter than a fuel cell on-orbit power system.

An assessment of the technology status of beryllium as related to structural application to space vehicles was presented to OMSF and OART personnel at NASA Headquarters on April 16.[74] Additional review of advanced materials development during this quarter included summaries of the generally unpublished work of the

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(71) Hard Ice Formation on a Heat Sink Booster, Memorandum for File, C. Bendersky, April 20, 1971.

(72) Further Comments - Hard Ice Formation on a Heat Sink Booster, Memorandum for File, C. Bendersky, June 21, 1971.

(73) Flywheel Energy Storage for the Space Shuttle Auxiliary Power Unit, Memorandum for File, R. Gorman, June 18, 1971.

(74) Beryllium - A Structural Material for the Space Shuttle, Memorandum for File, C. C. Ong, April 30, 1971.

Refractory Composites Working Group[75] and the structures and materials research activities in Europe that are related to the NASA Space Shuttle.[76]

Advanced propulsion technology studies were also monitored.[77,78] It was suggested that the Air Force Orbit-to-Orbit Shuttle studies, which include point designs of 25,000 pound thrust rocket engines, be expanded to include point designs of 10,000 pound engines, a thrust level of interest to NASA Space Tug and Space Shuttle on-orbital maneuvering propulsion.

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(75) Recent Progress in Refractory Composite Materials, Memorandum for File, C. C. Ong, May 12, 1971.

(76) The European Space Shuttle Structures and Materials Technology Programs, Memorandum for File, C. C. Ong, May 21, 1971.

(77) AFOSR Sixth Symposium on Advanced Propulsion Concepts, Niagara Falls, New York, May 4-6, 1971, Memorandum for File, C. Bendersky, May 24, 1971.

(78) Contents of AF/RPL Orbit-to-Orbit Propulsion Study, Memorandum for File, C. Bendersky, April 20, 1971.

Space Shuttle Applications

Studies of Space Shuttle utilization in spacecraft development testing continued in this quarter. The development history of the Orbiting Astronomical Observatory (OAO)[79] and Nimbus [80] were reviewed to identify tests which could have been advantageously conducted in orbit if the Space Shuttle were available. For the OAO, important orbital tests were identified such as (a) prototype testing of the fine pointing system, (b) thorough testing of electrical systems, (c) determination of spacecraft/solar array thermal and optical interactions, and (d) evaluation of materials. Nimbus orbital testing is less critical due to simpler requirements and the existence of extensive ground test facilities. On-orbit tests of solar panel deployment and materials outgassing and redeposition were the only Space Shuttle applications identified specifically. More generally, it was concluded that in addition to the examples cited, unmanned spacecraft development would benefit from periodic flights of spacecraft prototypes or models and diagnostic testing in orbit to determine failure causes.

Space Tug

Pre-Phase A studies of a number of different concepts for the Space Tug have been carried out by several contractors for NASA, European Launcher Development Organization (ELDO), and the Air Force. Several overall systems approaches were considered in accordance with different ground rules for the respective studies. These studies were reviewed and compared on the basis of factors including performance, cost, number and size of stages, mode of operation, propulsion, structure, tankage arrangement, avionics and interfaces with the Space Shuttle. Significant results were identified and recommendations toward establishing guidelines for further Space Tug studies were made in the course of participating in several meetings at NASA Headquarters with representatives of NASA, ELDO and the Aerospace Corporation.[81] In addition, the alternative main propulsion systems selected in

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(79) Shuttle Applicability to OAO Development, Memorandum for File, D. Macchia, April 21, 1971.

(80) Potential Use of the Shuttle as a Test Bed for Nimbus, Memorandum for File, A. S. Kiersarsky, April 2, 1971.

(81) Main Propulsion Selections; Pre-Phase A NASA Space Tug Studies, Memorandum for File, C. Bendersky, May 18, 1971.

these studies were compared.[82] In particular, a European concept for a new high pressure H_2/O_2 engine was evaluated in light of the current state-of-the-art.

Mission Analysis

The concept of pinpoint propulsive landing of a ballistic vehicle was examined including a survey of current and near future technology.[83] It was concluded that the concept is feasible, and it was estimated that a ΔV of approximately 1250 fps would be required for this maneuver. Further study of this concept identified fully automatic systems and radio updates of onboard inertial navigation to be basic requirements for its accomplishment.[84] Several distinct guidance phases during reentry and landing were identified and attendant control techniques were described.

A mission mode for repetitive logistics operations between low earth orbit and lunar orbit characterized by a two month periodic recurrence of a set of earth departure and lunar departure windows was described to illustrate a possible flight schedule for a Translunar Shuttle.[85]

Scientific Studies

A new approach to the modeling of eclipsing binary star systems was described.[86] Modern observational and analytical tools, including photomultiplier tubes, extremely stable voltage supplies and amplifiers, and digital computers, provide the possibility of obtaining and analyzing highly accurate light versus time curves of such eclipsing stars. The model described takes advantage of the computational power of a digital computer and thus allows a reduction in the number of simplifying assumptions. The validity of this model is tested through analysis of numerical integration errors, comparison with the spherical model, parametric studies, and application to observational data. It is concluded that the model is a valid representation of eclipsing systems, and that it is a useful tool for the analysis of such systems.

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(82) Pre-Phase A Tug Studies, Memorandum for File, A. S. Kiersarsky, H. S. London, D. Macchia, June 30, 1971.

(83) Pinpoint Propulsive Soft Landing of a Ballistic Vehicle, Memorandum for File, J. E. Nahra, April 12, 1971.

(84) Propulsive Landing of Ballistic Vehicles, Memorandum for File, C. S. Rall, June 30, 1971.

(85) A Possible Lunar Logistics Mode, Memorandum for File, E. M. Grenning, June 23, 1971.

(86) An Analytical Model of Eclipsing Binary Star Systems, TM-71-1011-4, D. B. Wood, April 16, 1971.

General

A review paper, An Analysis of the Dynamics and Thermodynamics of Water and Oxygen Particles in Space Based on Photographs Taken from the Ground During Apollo Missions, by R. D. Sharma, M. L. Kratage, and A. C. Buffalano was presented before the AIAA 6th Thermophysics Conference. Theoretical models describe the diffusion of such particulate clouds into space and consider their energy balance, temperature, and rates of sublimation. Photographic observations of oxygen dumps are fit by the model. The visual observations for water clouds are consistent with an extension of the model which is applicable to continuous releases in space.

SPECIAL TASK ENGINEERING STUDIES

Analysis of Haze Effects on Martian Surface Imagery

Task Order No. 35

In continuing support of mission planning for Mariner the current status of Mariner '71 TV camera inflight calibration was analyzed in view of the fact that only one spacecraft remains for the Mariner '71 mission and fewer pictures than previously anticipated will be available for the calibration. It is suggested that one picture per day is a realistic estimate of the number of pictures that can be allocated to calibration. Suggestions are made for test procedures that minimize the required number of calibration pictures. Absolute calibration of the camera, using Mars itself as a reference, provides a useful technique for monitoring the performance of the camera.

The geometric relationships that arise in carrying out atmospheric calculations were described for a spherical planet.[87] These relationships were developed for the specific case of light scattering from a planetary atmosphere or haze; however, the geometrical relationships are of general use in a wide range of problems that involve a spherical surface. A point in the atmosphere is described by two variables - its height above the surface of the spherical planet, and the angle between the local vertical through the point and the sun-planet axis. The direction of a line-of-sight from the local point is described by its azimuthal angle measured about the local vertical. Geometric relationships have been developed which give the coordinates of a new local point located a specified distance along the line-of-sight, as well as the directions of the line-of-sight at the new point.

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(87) Multiple Scattering Calculations: Geometry for Spherical Atmospheres, TM-71-1011-5, E. N. Shipley, April 16, 1971.

ENGINEERING SUPPORT

Computing Facility

The operations of the Univac 1108 computer continued with the EXEC 8 multiprogramming system. The computer usage for the quarter for NASA work was 454,981 charge units, of which 11,018 charge units were used by NASA Headquarters.

LIST OF REPORTS AND MEMORANDA

(List on Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Prior Experience with the Skylab Airlock Battery Cell, Memorandum for File, W. W. Hough.	March 31, 1971
Potential Use of the Shuttle as a Test Bed for Nimbus, Memorandum for File, A. S. Kiersarsky.	April 2, 1971
A Reconsideration of Copernicus as an Apollo Candidate Site, Memorandum for File, N. W. Hinners.	April 5, 1971
Statis Response - Axisymmetric Shell, Memorandum for File, S. Kaufman.	April 6, 1971
Apollo 15 Traverse Plan Briefing, Memorandum for File, P. E. Reynolds.	April 8, 1971
Pinpoint Propulsive Soft Landing of a Ballistic Vehicle, Memorandum for File, J. E. Nahra.	April 12, 1971
The Effect of Approach Azimuth and Sun Elevation at LM Landing on Mission Design for Apollo 16 and 17, Descartes or Copernicus, TM-71-2013-1, R. J. Stern.	April 13, 1971
Ascent Stage Limit Weight for Apollo 15, Memorandum for File, W. O. Covington.	April 14, 1971
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